

Internal Waves on the Continental Margin

Clinton D. Winant and M. C. Hendershott
Scripps Institution of Oceanography 92093-0209
Grant No. N00014-96-1-0031

Project Activity

Internal wave 'antennas' composed of moored acoustic doppler current profilers (ADCP's) generally covering the middle 80% of the water column augmented by one to seven continuously recording temperature loggers distributed along the mooring line were deployed in waters just offshore of San Diego at depths ranging from 15 m to 500 m during the summer and fall of 1996 and 1997. The first was deployed from 25 June to 5 September 1996 with five moorings between the 15 m and the 350 m isobaths along a central transect extending offshore from Mission Beach (San Diego) plus two more deployed north and south of the 30 m mooring along the 30 m isobath. At each mooring a bottom mounted ADCP looked upward, and the mooring line was instrumented with continuously recording temperature sensors. At both deployment and recovery, 12 hour CTD yoyos were carried out at a number of the mooring sites as well as at a station on the 500 m isobath offshore along the central transect line. A second deployment of eight ADCPs was carried out between 17 September and 24 October 1996 along the same central transect line but with one ADCP on the 100 m isobath and the rest closely spaced (about 250 m spacing) between the 15 and 30 m isobaths. The first deployment during 1997 was somewhat similar to the second of 1996, except that the 500 m and 350 m moorings were outfitted with two adcps each mounted on the mooring line so as to give nominal coverage of the upper 200 m of the water column. The second deployment of 1997 consisted of two parallel on-offshore lines 500 m apart, each extending from 30 m to 15 m water depth. Simultaneous meteorological observations are available from Scripps Pier in La Jolla. CTD yoyo's were carried out over periods ranging from about 3 to about 24 hours during mooring deployment, service and recovery, and a bottom pressure sensor was deployed at the 15 m mooring. Work since instrument recovery has consisted of data management and analysis. The results will constitute the PhD thesis of graduate student Jim Lerczak.

Scientific Results

Tidal band variability. The internal tide showed surprising variability of vertical structure from deep to shallow moorings, and between semidiurnal and diurnal bands. Tidal variability was intermittent, and not obviously correlated with the fortnightly and/or declinational cycles of the semidiurnal and diurnal surface tide or with lower frequency changes in background currents or stratification. Surprisingly, strong diurnal (0.042 cph) currents were present on the slope and shelf, even though the diurnal frequency is slightly subinertial at San Diego (inertial frequency 0.045 cph).

The spatial structure of the tidal variability was studied separately for bands centered about diurnal (0.030 to 0.056 cph) and semidiurnal (0.056 to 0.11 cph) frequencies using

complex empirical orthogonal functions (cEOFs). Most of the variability in each band was captured by a single dominant cEOF. However, the structure of the dominant mode was strikingly different for the two bands. Diurnal currents were surface enhanced, and decayed gradually from the slope shorewards. They were clockwise circularly polarized and generally showed slow upward phase propagation (0.05 mm/s). This upward phase propagation was surprising for motions that were apparently subinertial, and therefore evanescent, at this latitude. The driving agent for these motions is presumed to be the local sea breeze, which had a very pronounced diurnal spectral peak.

Semidiurnal currents were stronger on the shelf than over the slope. The dominant CEOF for on-offshore currents had internal mode one structure. But bottom currents were linearly polarized in the cross-isobath direction while the surface currents were clockwise circularly polarized. There was no apparent vertical phase propagation for these waves. The relative phase between cross-isobath semidiurnal currents at different depths and temperature fluctuations was consonant with standing wave structure in the cross shore direction. Near bottom semidiurnal currents on the slope (350 m water depth) were an exception to this general description; here the semidiurnal currents were bottom enhanced, linearly polarized in the along-isobath direction, and tightly coupled to the fortnightly cycle of the surface tide.

High frequency variability. Mode one internal waves explain approximately 80% of the high-frequency (buoyancy frequency to 1 cph) variance in shallow water (15 to 30 m). The critical internal wave frequency for the nearshore region of the continental slope is approximately 7 hours, so that the high-frequency waves are very subcritical. The internal wave field is dominated by onshore propagating undular bores and solitary-like events, in addition to apparently independent near-buoyancy frequency motions. Wave packets generally arrive at the nearshore study site on a semi-diurnal schedule. Long-wave phase speeds decrease from approximately 25 cm/s to 12 cm/s as the waves propagate from a water depth of 30 m to 15 m. The dissipation time scale is approximately 2 hours, so that the waves decay significantly over the time (approximately 3 hours) it takes them to cross the nearshore array ($\Delta x = 1.5$ km). A simple dissipative linear model cannot carry 30 m data to the 15 m mooring. There is little or no correlation in the high-frequency band between the 70 m and 100 m records with the 15 to 30 m records.

Published Abstracts for Papers Given at national Meetings:

Lerczak, J., NM. Hendershott and C. Winant (1999). Observations of the Internal Tide on the Southern California Shelf. 1999 Aha Hulikoa Workshop, Internal Wave Modelling, 19-22 January 1999.

Lerczak, J., C. Winant and M. Hendershott (1998). A study of dissipative, high-frequency internal waves in shallow water. Internal Solitary Waves Workshop, 27-29 October 1998 contributed paper
(<http://www.whoi.edu/science/AOPE/people/tduda/isww/text/>)

Lerczak, J.A., M.C. Hendershott, and C.S. Winant (1998). Observations of high-frequency internal waves off of Mission Beach, CA. Presented at the Ocean Sciences Meeting. 9-13 February, San Diego, CA.

Lerczak, J.A., C.D. Winant, and M.C. Hendershott (1998). Linear analysis of high-frequency internal waves in shallow water. Presented at the Eastern Pacific Oceanography Conference. 23-26 September, Mt. Hood, OR.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average one hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 4/25/00		3. REPORT TYPE AND DATES COVERED Final Technical Report / 11/1/95 - 10/31/98
4. TITLE AND SUBTITLE Internal Waves on the Continental Margin			5. FUNDING NUMBERS ONR N00014-96-1-0031	
6. AUTHOR(S) Clinton D. Winant and Myrl C. Hendershott				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Scripps Institution of Oceanography, Center for Coastal Studies 9500 Gilman Drive La Jolla, CA 92093-0209			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research Attn: Dr. Louis Goodman 800 North Quincy Street Arlington, VA 22217			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Internal wave antennas composed of moored acoustic doppler current profilers (ADCP's) generally covering the middle 80% of the water column plus one to seven continuously recording temperature loggers distributed along the mooring line were deployed in waters just offshore of San Diego at depths ranging from 15 m to 500 m during the summer and fall of 1996 and 1997. Simultaneous Meteorological observations are available from Scripps Pier in La Jolla. CTD yoyo's were carried out over periods ranging from about 3 to about 24 hours during mooring deployment, service and recovery, and a bottom pressure sensor was deployed at the 15 m mooring. The data provide a new degree of vertical and horizontal resolution of the velocity and temperature fields associated with internal tidal band motions (including diurnal motions apparently driven by the land-seabreeze cycle) and borelike and apparently solitary disturbances in shallow (tens of m) water during summertime.				
14. SUBJECT TERMS Internal tides Diurnal motions Inertial Motions Shallow water Solitary Waves Solibores			15. NUMBER OF PAGES 5	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unrestricted	18. SECURITY CLASSIFICATION OF THIS PAGE Unrestricted	19. SECURITY CLASSIFICATION OF ABSTRACT Unrestricted	20. LIMITATION OF ABSTRACT None	